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The general objective of this project is to study radiative transitions in atoms and molecules, particularly those relevant to infrared radiation. Our major efforts include (a) study of electron-impact dissociative excitation of oxygen and its mechanism, (b) production of excited nitrogen atoms and their infrared emission by electron impact on nitrogen molecules, (c) development of a method for determining number density of metastable atoms produced by electron beams, (d) study of collisional behaviors of 3s lone electrons.

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AFOSR-TR- 87-0813

Final Scientific Report

Grant AFOSR-83-0312, 1 August 1983 - 31 January 1987

Principal Investigator: Chun C. Lin

The general objective of this project is to study radiative transitions in atoms and molecules, particularly those which are relevant to infrared radiation. Our major efforts were in the following areas:

(i) Passage of an electron beam to a chamber containing O_2 molecules produces excited O_2 molecules in bound electronic states as well as unbound states. In the latter case the excited molecule dissociates into two oxygen atoms with one or both in excited states. To study this process we measure the radiation from the excited oxygen atoms produced by electron impact on O_2 molecules. We have measured absolute optical emission cross sections for a large number of transitions originating from excited electron configurations $1s^2 2s^2 2p^3 n\ell$ (n=3,4,5,6,7,8) of the oxygen atom produced by incident electron energy from threshold to 500 eV. (Production of oxygen atoms in the highly excited levels is of special interest because such highly excited atoms are sources of infrared radiation.) Studies of detailed characteristics of the energy dependence of the cross sections (including the appearance potential) allow us to identify the key mechanisms for producing the excited oxygen atoms in the electron-impact dissociation experiment. The excitation functions show a broad peak at about 90 eV with a shoulder-like structure of varying degree near 35 eV. The observed threshold energy is very close to the energy defect of the dissociation process. Near the threshold, dissociative excitation through partly bound Rydberg states of the oxygen molecule is believed to be a major mechanism for producing the observed atomic-oxygen emission, whereas simultaneous ionization and excitation followed by dissociation becomes important at energies

above 50 eV. Absolute optical emission cross sections for a series of atomic-oxygen transitions in the long-wave infrared region have been obtained.

(ii) Production of excited nitrogen atoms $1s^22s^22p^2n\ell$ in the low excited states (n=3,4) by electron-impact dissociation was previously reported in the literature. Nitrogen atoms in the highly excited states are of special importance because of the intrinsic interest in atomic physics and their potential roles as infrared emitters. Therefore we have conducted a study of production of excited nitrogen atoms in the highly excited states of n=5,6,7,8,9. Excitation cross sections and excitation functions for optical emission of some fifty transitions of the type $1s^22s^22p^2n\ell \rightarrow 1s^22s^22p^2n'\ell'$ have been measured. Like the case of oxygen, the cross section data, especially the variation of the cross section with incident electron energy, provide information about the key mechanisms for the production of the excited nitrogen atoms. Absolute optical cross sections for a series of atomic-nitrogen transitions in the long-wave infrared region have also been obtained.

(iii) A new method for determining the number density of metastable atoms produced by electron-beam excitation of ground-state atoms has been developed in our laboratory and applied successfully to neon. We generate metastable Ne atoms (in the $1s^22s^22p^53s$ electron configuration) by an electron beam through a container of Ne atoms. A pulsed laser, tuned to the absorption frequency of one of the $1s^22s^22p^53s \rightarrow 1s^22s^22p^53p$ transitions, pumps the metastable atoms to a $1s^22s^22p^53p$ level. With a high-power pulsed laser we saturate the transition, i.e., transfer the atoms from the $1s^22s^22p^53s$ metastable level to the higher $1s^22s^22p^53p$ level to equalize the population of these two levels. The number of photons emitted from this $1s^22s^22p^53p$ level after cessation of the laser pulse is measured and used to determine the number density of the metastable Ne atom number density. At a Ne gas pressure of 15 mTorr, an electron beam current

density of 0.016 A/cm^2, and an electron beam energy of 100 eV, we find the number density of the metastable Ne atoms in the $1s^2 2s^2 2p^5 3s$, J=2 level to be 9×10^8 cm^{-3}. Comparing this with the ground-state atom number density of 5×10^{14} cm^{-3}, we find a metastable atom concentration of about one or two parts in 10^6.

(iv) As a way to understand the collisional behaviors of the Ne($1s^2 2s^2 2p^5 3s$) metastable atoms, we try to have some indications as to the roles played by the 3s electron under various collision conditions. The 3s electron is a "lone" electron in an outer shell and relatively loosely bound, so it is in some way similar to the 3s electron in a ground-state Na atom ($1s^2 2s^2 2p^6 3s$). Because of its small binding energy, the 3s electron can be readily excited to the higher levels, ionized, or, upon colliding with another atom, may transfer to the collision partner. Thus we have conducted collision experiments of Na atoms with H^+, H_2^+, H_3^+, H^- ions and neutral H atoms as projectiles, and measured the cross sections of 3s $\rightarrow$ 3d excitation and of electron transfer, H + Na $\rightarrow$ H^- + Na^+. At the same projectile velocity, the Na(3s$\rightarrow$3d) excitation cross sections are the same for H^+, H_2^+, H_3^+, and the same for electron projectile when the projectile velocity is somewhat above the electron excitation threshold. However, the Na(3s$\rightarrow$3d) excitation cross sections due to H^- ion impact are about 45% lower than the corresponding cross sections due to H^+, H_2^+, H_3^+, and electron impact at the same projectile velocity. These results provide very valuable information about the collisional properties of the various partners.

Publications

"Excitation of the Na(3p) Level by H^- Ions and H^o Atoms", Physical Review Letters 51, 2029 (1983).

"Charge Changing Cross Sections for 1-25 keV H(1s) Incident on a Na Vapor Target", Physical Review A 29, 1083 (1984).

"Electron-Impact Excitation of the $D^3\Sigma_u^+$ and $c_4'{}^1\Sigma_u^+$ Rydberg States of N_2", Physical Review A 29, 1709 (1984).

"Emission from Oxygen Atoms Produced by Electron-Impact Dissociative Excitation of Oxygen Molecules", Physical Review A 32, 2100 (1985).

"Electron Excitation Cross Sections for the Metastable and Resonant Levels of $Ne(2p^53s)$", Physical Review A 32, 2117 (1985).

"Emission from Atomic Niirogen Produced by Electron Impact on Nitrogen Molecules", submitted to the Journal of Chemical Physics.

Professional Personnel

Researchers associated with this project include the following:

(a) Senior researchers: C. C. Lin (Principal Investigator), L. W. Anderson, F. A. Sharpton.

(b) Graduate Students: J. S. Allen, A. R. Filippelli, J. E. Gastineau, A. M. Howald, M. B. Schulman, D.L. A. Rall.

Interactions

The principal investigator has regular scientific contact with Drs. Edward T. P. Lee and Randall Murphy in the Radiation Effect Branch, Optical Physics Division of the Air Force Geophysics Laboratory (Bedford, Massachusetts).